

# THE ENVIRONMENTAL ELECTROMAGNETIC MODELLING SYSTEM (EEMS) PROJECT OVERVIEW.

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## INTRODUCTION.

The EEMS project was set up by the MWC (Maritime Warfare Centre) as a result of a priority one tasking from the UK Royal Navy's Meteorological Staff to develop an operational replacement for the Integrated Refractive Effects Prediction System (IREPS).

Despite having been used operationally by the RN since the early 1980s, IREPS was only ever intended as a technology demonstrator. Although IREPS has been successful, it has several limitations associated with it. These include a lack of terrain handling, an inability to deal with elevated antennae, a limited in its ability to assess effect of rapidly changing refractivity. Perhaps the biggest constraint is that IREPS only provides an indication of presence of anomalous propagation (ANAPROP), this is not of sufficient detail to quantitatively assess the impact of ANAPROP.

Since IREPS there have been many advances in the computational methods available to calculate the effect of the environment on electromagnetic wave propagation, and EEMS is to take advantage of these emerging techniques. [Lewis and Moore, 1995].

Since EEMS was always intended to be an operational package it was necessary that it should operate in "real time". For the purposes that EEMS is intended, "real time" means that all calculations and data processing must be completed within an operationally useful time frame [Moore and Lewis, 1994]. For example if the aircrew of an airborne early warning platform is to be briefed on the likely effects of the environment upon their radar coverage then the output of the tactical decision aids within EEMS must be available in minutes not hours.

The overall aim of EEMS is to provide improved tactical advice by allowing a greater understanding of the effects of the current operational environment on the sensors and communications of the relevant platforms (e.g. air defence units).

## THE COMPONENTS OF EEMS

Although EEMS is to be the RN successor to IREPS it is not just a radar propagation model. The radar propagation model (TERPEM TERRain Parabolic Equation Model) is one module within the whole of EEMS. The components that comprise EEMS are an EM propagation model, Tactical Displays, a High Frequency Communications Model, Links to a terrain database/GIS system and an Electro Optic Tactical Decision Aid (EOTDA).

For example, if an operation was taking place in a littoral region the tactical display/GIS system would be used to plot the positions of a task group's platforms. EEMS can then take, directly from the Geographical Information System(GIS) terrain database, all the relevant geographical information to allow the other components to determine the effect of the terrain on sensor/communications coverage. This component of EEMS is still currently under development at MWC.

## DEVELOPMENT PHASES

EEMS is to be developed in three phases, the two earlier phases having been completed. An outline of the development phases is given below:

Phase 1 (completed July 95): Includes the prototype radar propagation model and the development of tactical displays.

Phase 2 (completed July 96): Includes enhancements to the radar model and a prototype human-computer interface.

Phase 3 (expected 1997): Includes the HF communications model integration, the interim EO TDA integration and platform stationing and tracking algorithms.

## EM-WAVE PROPAGATION MODEL

The principal module within EEMS is the EM-wave propagation model, and as such the choice of the particular model used was of high importance.

In determining the choice several factors had to be considered. Firstly, the output had to be of greater fidelity than IREPS and be able to produce a high degree of user confidence. The analysts at MWC were already familiar with tools such as PC-PEM. This model had been extensively used in analysis of naval operations and the fidelity of its' output considered sufficient. The main draw back of this package was the length of time needed to calculate the coverage of radars especially for the case of elevated antennas (typically many hours). For an operational tool then the radar model would have to operate in a time frame that is operationally useful, typically around a minute to calculate the coverage of an airborne radar.

The objective in developing the EM\_wave propagation model was to investigate the relationship between accuracy and time- *could a high fidelity solution (e.g. PE models) be made timely and could a fast analytical solution (e.g. ray tracing) be sufficiently precise?*

Approaches using both techniques were considered using the criteria of varying fidelity, range dependency and timeliness. However it was found that neither approach fully met the EEMS performance requirements. Despite this both approaches offered considerable improvement on IREPS.

Consequently it was apparent that a phase of development would be needed to meet the requirements for EEMS. Taking into account the level of fidelity, user confidence and the technical (and financial) risks associated with development it was concluded that the PE-Hybrid approach (TERPEM) would be the most suitable way ahead. The development of TERPEM is described by Levy and Craig [1996]

### TACTICAL POST PROCESSING AND MEASURES OF EFFECTIVENESS

Typically the output from a propagation model has been presented in the form of a vertical coverage diagram of either path loss or conventional probability of detection. This type of approach allows a subjective assessment of when a target is likely to be detected. For the purposes of platform stationing further processing needs to be carried out in order to provide an objective assessment and degree of confidence in the level of coverage provided by a sensor.

Within EEMS a suite of software has been created to allow a further degree of tactical post processing beyond the traditional probability of detection. This

incorporates the dynamic and operator factors that are all part of an operational radar system. Figure 1 below displays all the major components that are part of a radar system

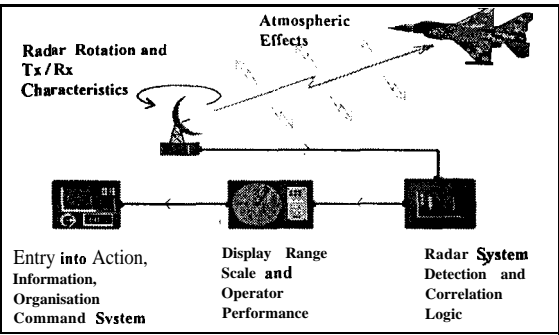


Figure 1: Components of a radar system

For operational assessment a radar system consists not only of the antenna/receiver, signal generator and detection logic but also factors such as the operator performance, and how the information from the operator is delivered to the command team. Until the target details are injected into the action information organisation (AIO) system a response cannot be made. The dynamic nature of an AAW scenario can have a large impact on the detection range as will be shown later.

The software developed to carry out the processing of the radar model output is known as the Target Detection Range Software Suite (TDRSS). The two components of TDRSS are the MWC developed models PRAM (Predator Radar Model) and PREDATOR (Predicted Detection Ranges of Airborne Targets in Operational Regimes). Although detailed in detail by Williams and Ayoola [1996] PRAM is essentially a conventional application of the radar range equation using the physical parameters of the system of interest to produce a continuous curve of probability of detection (PoD) against range. PREDATOR is used to consider the dynamic situation by means of a Monte Carlo approach. This includes the effects such as aerial rotation rate, target speed, detection logic and operator factors. The full list of factors included are the radar aerial rotation rate, a valid contact criteria (n returns above threshold OUT OF m sweeps of aerial), the operator efficiency, the operator delays, the radar range scales and the target speed.

By considering the cumulative frequency of detections (number of simulated detections as a percentage of total number of simulations) as a function of range a Tactical Radar Range (TRR)

can be defined. The MWC definitions of PoD and TRR are given below:

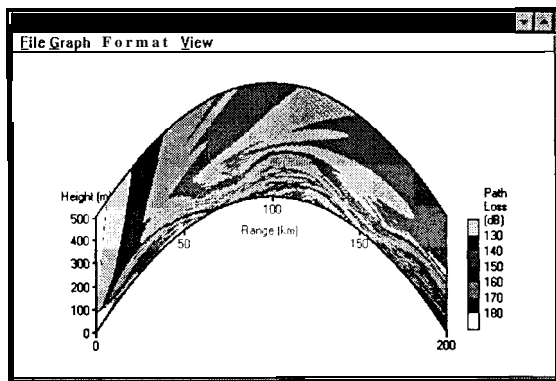
**Probability of Detection:** *the range for a given probability that a static but fluctuating target will be illuminated and provide a paint on an operator's display.*

**Tactical Radar Range:** *the range, for a given probability, that a valid contact is recognised by the operator and injected into the tactical system,*

In order to appreciate the differences between PoD and TRR (and the advantage TRR provides in terms of platform stationing) it is necessary to examine an example of the type of analysis EEMS can provide.

### EXAMPLE OF MEASURES OF EFFECTIVENESS.

For this example the refracting environment is assumed to be a strong low level duct extending up to approximately 300 metres. A surface based antenna is placed within the duct. The path loss was calculated using TERPEM and is displayed below in figure 2.

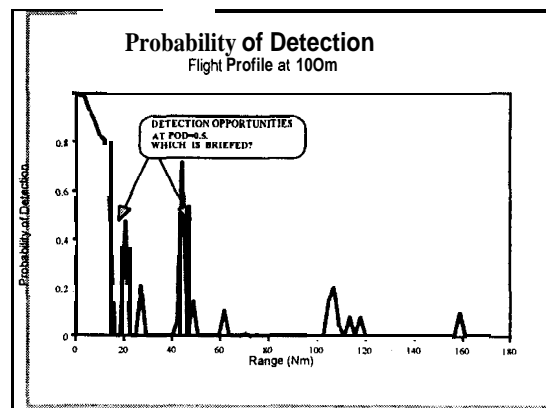


**Figure 2: Path loss diagram calculated using TERPEM.**

A target is assumed to be flying directly toward the antenna at an altitude of approximately 100 metres. As can be seen from figure 2 extended detection ranges would be expected against low flying targets. However some quantitative estimate of the range at which this target would be detected is required in order to aid a command team to deploy their assets effectively. Traditionally this has been done by application of the radar range equation to calculate the probability of detection as a function of range.

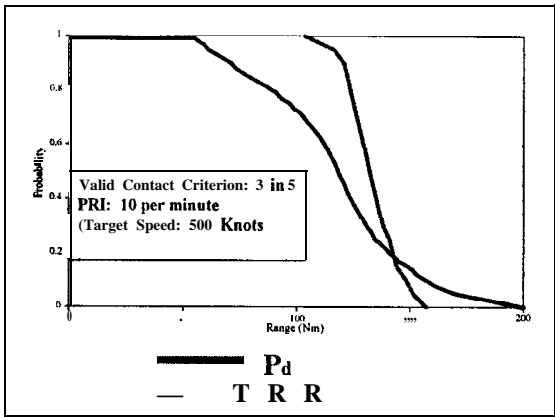
Figure 3 below displays the PoD as a function of range for a target flying toward the antenna at a height of 100 metres. The presence of the duct

makes itself felt with the PoD being very discontinuous. This provides a problem in defining a detection range for planning purposes. If a 50%/0 PoD is to be used as the basis of the range then there is an ambiguity as to whether the range is 45 miles or 18 miles. Making a decision as to which range to use means making a subjective assessment, which is to a degree defeating the point of applying a quantitative analysis.



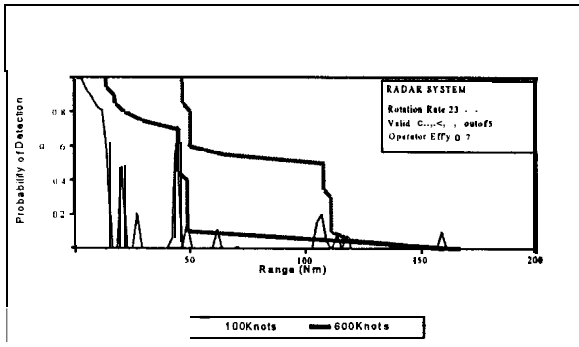
**Figure 3 Probability of detection as a function of range.**

It is at this stage that PREDATOR would be used to further process the conventional PoD curve to generate a cumulative frequency graph of the number of detections made against range. The effect of including the dynamics of the scenario plus the valid contact criterion is to allow a non-ambiguous single value for the detection range based upon the percentage of targets that would have been detected at that range. If this approach is applied to a smooth and continuous PoD curve as might be expected in standard refracting conditions, the effect is to produce a curve with a profile that tends toward a step function. An example is displayed below in figure 4. This is effectively a "cookie cutter" for the detection range and as such is heavily used in search and screening doctrine to determine optimum asset placement [United States Naval Institute, 1977].



**Figure 4 Effect of application of PREDATOR on a smooth PoD curve.**

For the problem of a discontinuous PoD curve as in figure 3, the application of PREDATOR is particularly useful. Since the dynamics of the situation are now being considered it enables the command team to appreciate the impact of these dynamics upon the tactical situation. In figure 5 below the TRR curves for a target traveling at 100 knots and at 600 knots are overlaid on the PoD curve. As can be seen the slow moving target presents enough opportunities for illumination around 110 NM that by this range 50% of the targets would have been detected and the radar operator alerted. The fast moving target however has usually passed through the small detection possibility at 110 NM and usually isn't recognised until approximately 45 NM. Being able to consider such factors can have a major impact on the stationing of assets. In a simplistic approach it could be said that if the threat is expected to be relatively slow then assets could be spread further since the TRR for this threat larger. For the 600 knot target units would have to be placed closer together to provide seamless coverage.



**Figure 5 Effect of target speed on Tactical Radar Range**

This approach makes the assumption that the target is flying directly toward the antenna. This may be a reasonable assumption if the antenna happens to be

attached to the mission essential unit in a task group. A more likely scenario is that the TRR for an air de fence ship is going to be needed against a crossing target. Modifications have already been made to the components of EEMS to take into account changing aspect of target and the other factors needed to assess the coverage against crossing targets.

## HF COMMUNICATIONS MODULE

The HF communications model is derived from JIVE (Jamming Interception Vulnerability Estimator) which was originally developed at DRA Malvern. The details of this module are detailed by *Moore and Shukla [1996]* and *Shukla et al [1996]*.

## LINKS TO TERRAIN DATABASE

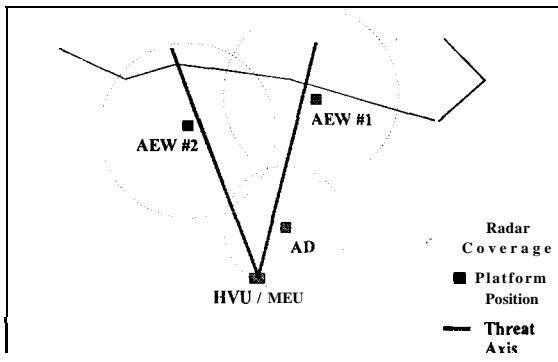
When conducting littoral operations the ability to predict inshore/overland radar/radio coverage is essential, hence terrain features are an important data requirement. Phase three of EEMS will incorporate a GIS system which will provide all necessary geographical information. The tactical displays and terrain database will provide both a visual display of sensor/communication coverage and act as a method of defining the scenario, in effect acting as both the input and output of EEMS.

## ELECTRO-OPTIC TDA

The Electro-Optic Tactical Decision Aid (EO TDA) is being sourced via an international exchange program with the US Navy.

## FUTURE DEVELOPMENTS

The prime reason for presenting the coverage as the Tactical Radar Range is to enable the command team to deploy their assets to their best advantage. As mentioned above, the single valued nature of the TRR allows the coverage range for an acceptable confidence level (for example 95% of targets will have been recognised and the unit alerted) to be considered as a "cookie cutter". This can be used to simply display this coverage visually and overlay on some form of map display (see figure 6).



**Figure 6: Platform stationing using TRR to define a simple “cookie cutter”.**

The underwater warfare community has for many years used the Tactical Sonar Range (TSR), and using this range developed many useful search and screening type doctrine. The tools are now available in the above water warfare world to be able to take account of the environment and determine its’ impact on sensors and consequently tactics. By making use of concepts such as TRR it is now possible to make use of the lessons learnt in the underwater world, and their ability to exploit the environment to their advantage, and use them for a fresh approach to above water warfare doctrine and analysis.

## SUMMARY

The EEMS project is aimed at providing the above water community with a tool that enables the command team to exploit the environment to their advantage. The final product will allow the user to determine the coverage of both radar and electro-optic sensors and the coverage of radio communications. By incorporating concepts such as TRR with modern GIS systems, classical search and screening doctrine can be applied and optimised to the above water environment. This can be used for optimal asset deployment.

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